National Renewable Energy Laboratory

Technical and Economic Assessment: Review and Proposed Directions

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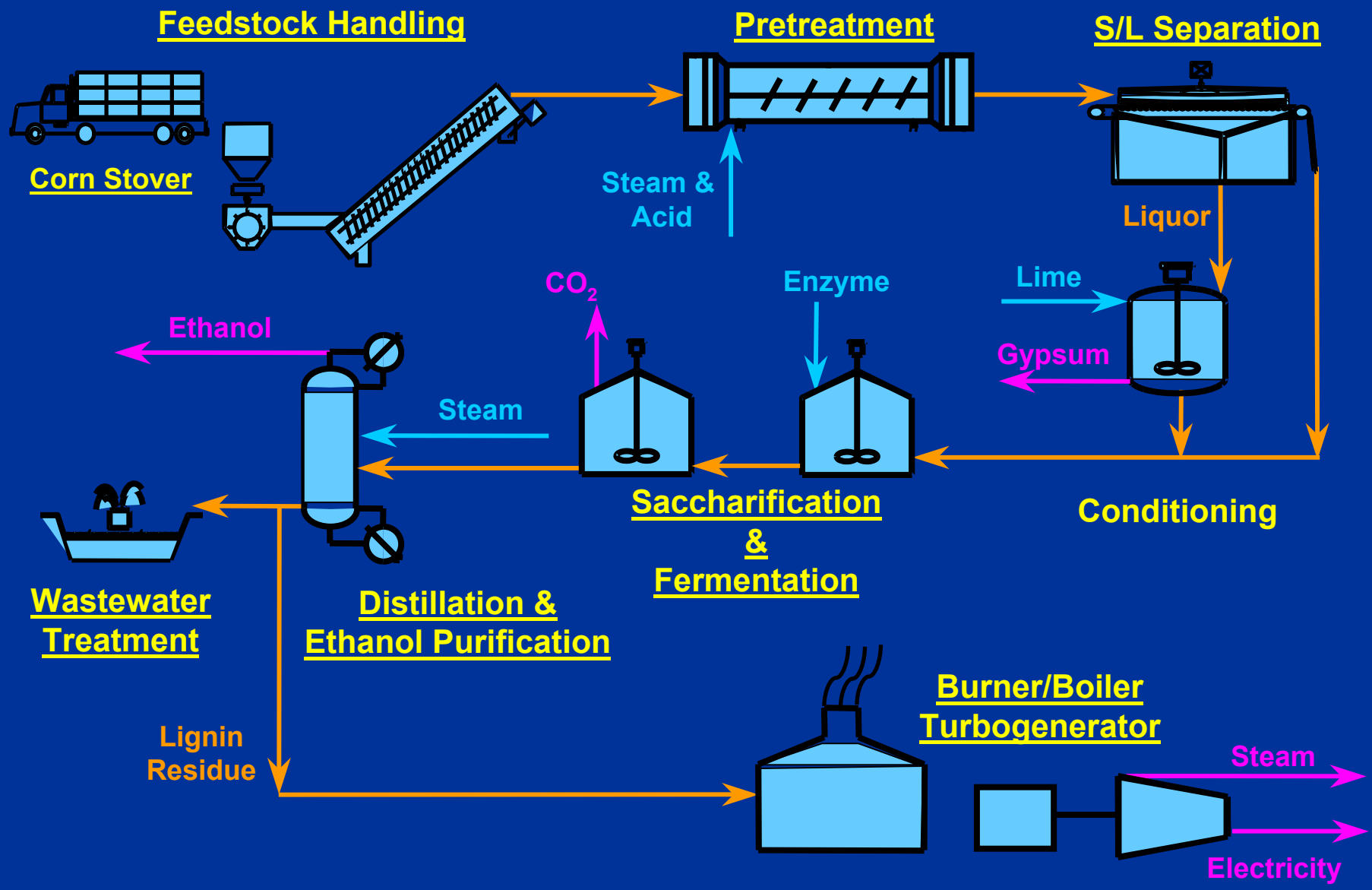
National Renewable Energy Laboratory

Target-Case Report

- Design Report published in 2002 (NREL/TP-510-32438)
  - www.nrel.gov/docs/fy02osti/32438.pdf
  - ASPEN input code and Excel spreadsheets are available upon request
- Material and energy balances calculated with ASPEN+
  - 63 components tracked through 164 unit operation blocks
  - 82 control blocks
- Minimum Ethanol Selling Price ($ per gallon ethanol)
  - Near-term estimates: Relative values between research options used to assist in guiding research
  - Long-term estimates: Absolute values used for policy analyses


Feedstock Handling
Pretreatment
S/L Separation
Corn Stover
Steam &
Acid
Liquor
Lime
Gypsum
CO_2
Enzyme
Ethanol
Steam
Saccharification
&
Fermentation
Conditioning
Wastewater
Treatment
Distillation &
Ethanol Purification
Lignin
Residue
Burner/Boiler
Turbogenerator
Steam
Electricity

Target Process Economics

Plant Size: 2200 tons (2000 MT) Dry Corn Stover/Day (Greenfield Site)
Corn Stover Cost: $30/dry ton

Economic Parameter (Units, $2000)	Value
Minimum Ethanol Selling Price ($/gal)	$1.07
Ethanol Production (MM gal/yr)	69
Ethanol Yield (gal/dry ton stover)	90
Total Project Investment ($ MM)	$197
TPI per Annual Gallon ($/gal)	$2.86
Minimum Sugar Selling Price ($/lb)	$0.056

Comparison of Target Parameters to NREL Measured Data

Parameter	Target	2002 Data	MESP Difference
Minimum Ethanol Selling Price ($/gal)	$1.07	$2.42	$1.35
Pretreatment Concentration	30%	19%	$0.29
Pretreatment Monomeric Xylose Yield	90%	67.5%	$0.12
Enzyme Cost ($/gal)	$0.10	$0.64	$0.54
Cellulose Hydrolysis Yield	90%	90%	$0.00
Fermentation Sugars	All 5	Glucose / Xylose	$0.12

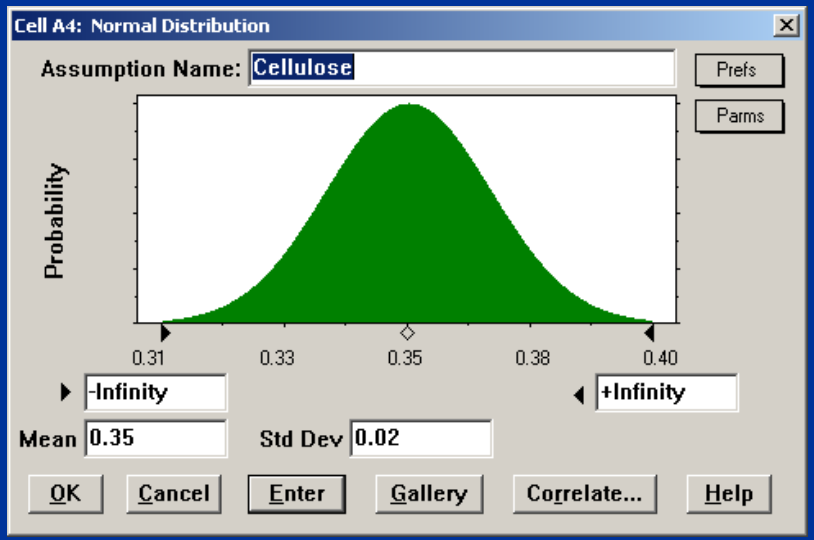
Pioneer Plant Costs

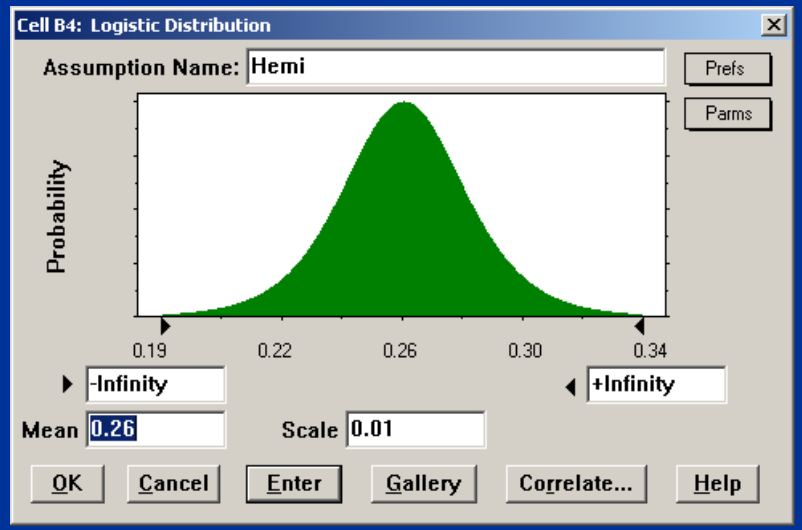
- Addresses technical and economic risk in the first-of-a-kind plant (Rand Corporation, 1981)
- Pioneer plant MESP: $1.54-$2.03 / gal
  - 44%-90% cost growth
- Systematic issues
  - Material and energy balances
  - Analytic chemistry
  - Impurities and their effects

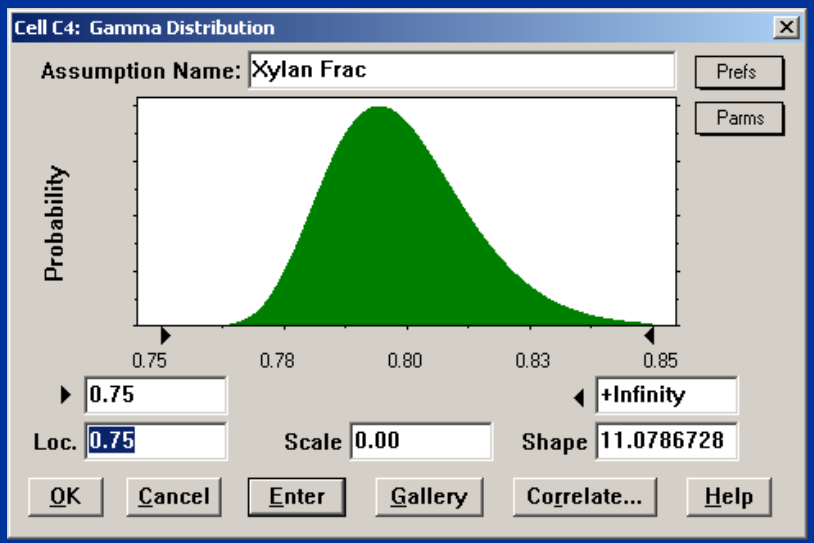
Monte Carlo Analysis

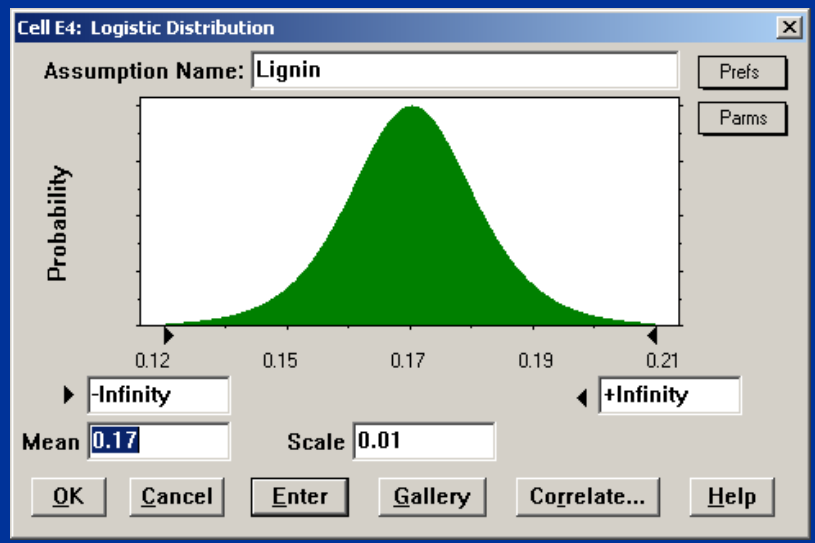
- Uses random numbers within defined functions to predict the uncertainty of modeled systems
  - Packaged software (e.g., Crystal Ball) makes it easier with Excel
- Used in the environmental, safety, business and other fields
- First analysis: Varying feedstock composition and high-impact process yields
  - Attempt to show potential variation in a working facility

Monte Carlo Analysis Parameters









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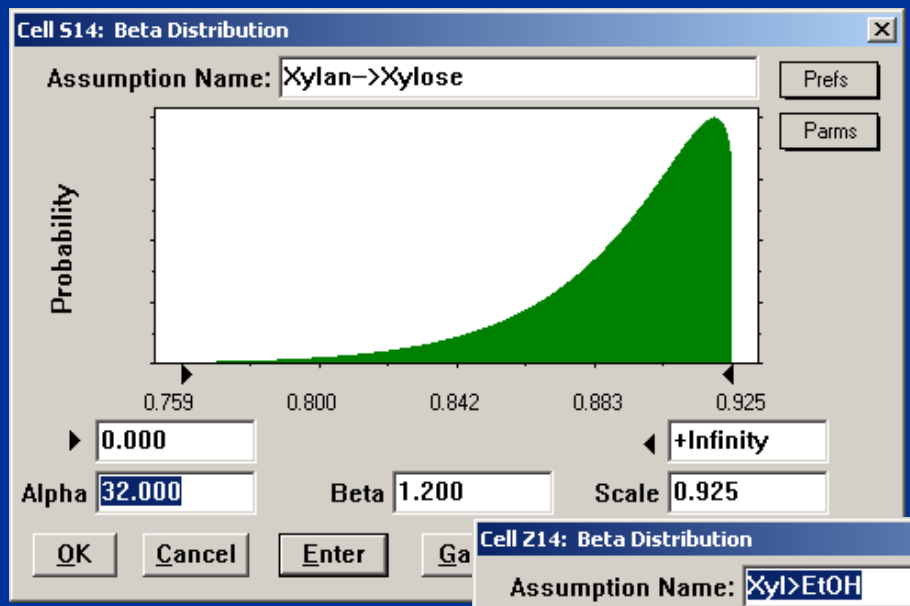
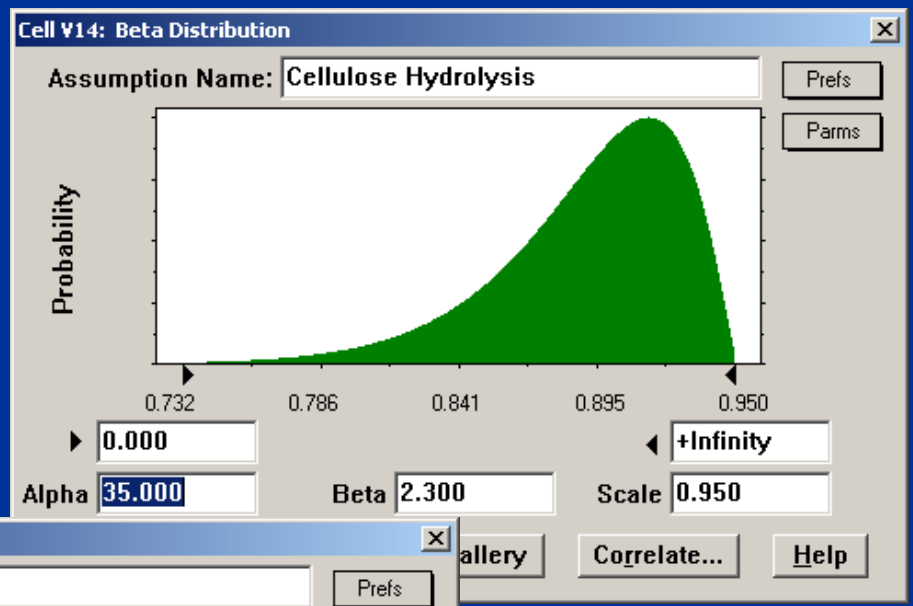
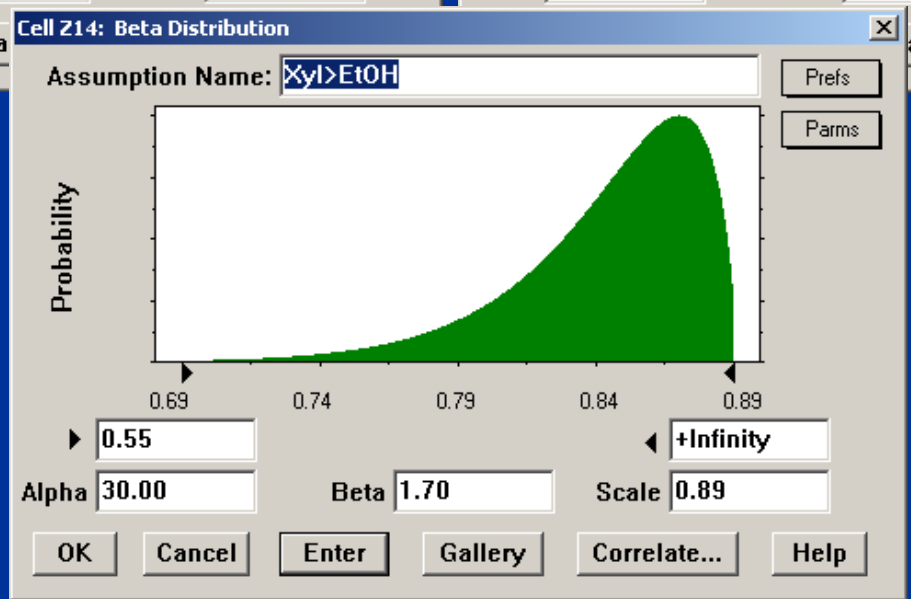
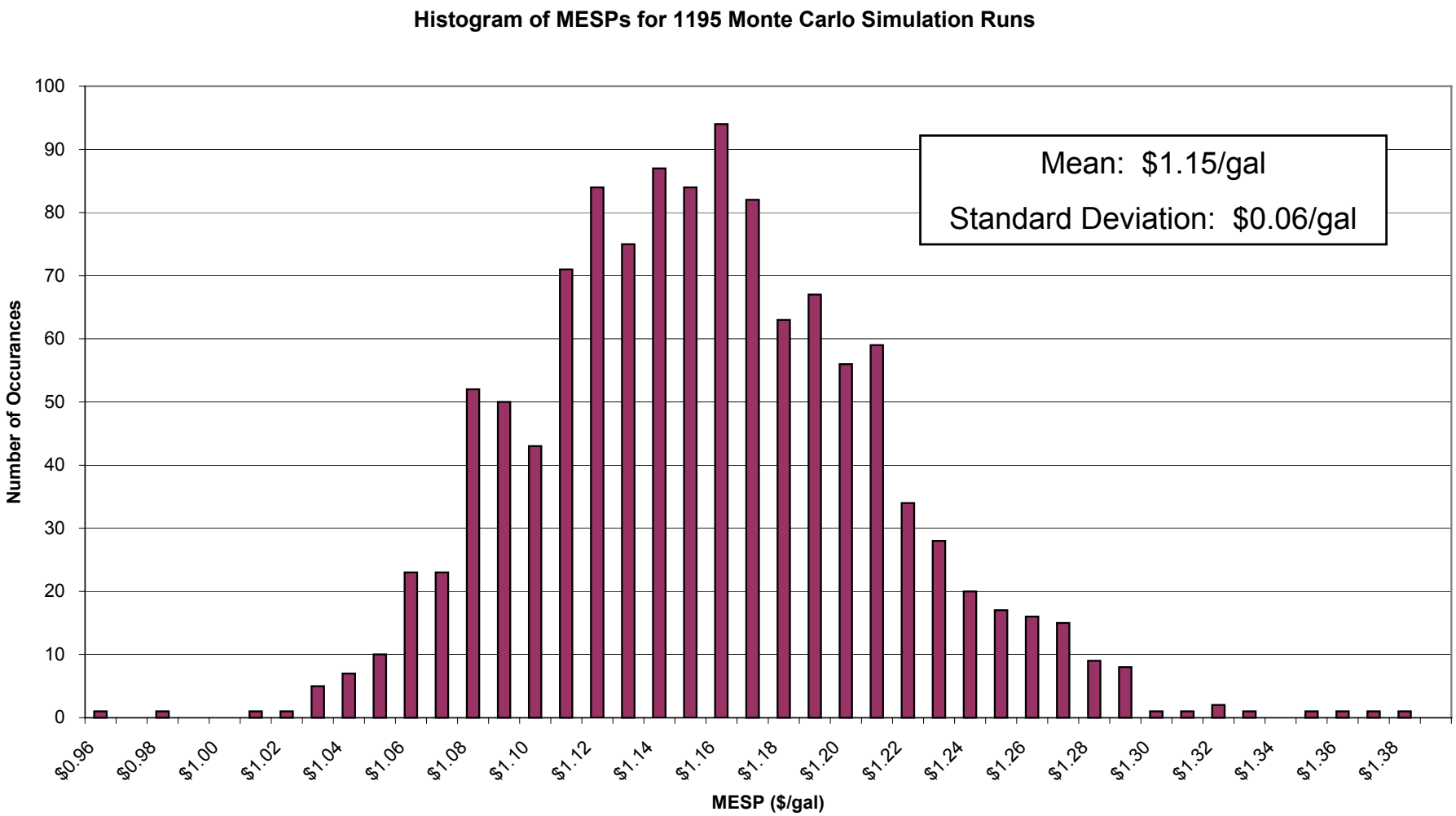






Monte Carlo Analysis Results



Recommendations for Near-Term Work

- Legal and regulatory issues
  - Improve understanding of emissions issues and modify design to achieve emission regulations
- Technical feasibility and risk
  - Improve biomass handling and storage design
    - Links with biomass harvest strategy
  - Modify solid/liquid separation parameters to match pilot-scale measurements
  - Improve modeling of conditioning (i.e., overliming) process area
  - Improve model's material balance by tracking additional components

Recommendations for Long-Term Work

- Technical feasibility and risk
  - Continue to track technology status
  - Link economic risk analysis to research error analysis
- Competitive advantage
  - Improve understanding of feedstock cost structure
- Strategic fit
  - Include kinetic models to develop an economic optimization tool
  - Develop LP models for biorefineries

Team Members

- Andy Aden
- Kelly Ibsen
- John Jechura
- Bob Wallace